OSRAM
Opto Semiconductors

Preventing LED failures caused by corrosive materials

Application Note

Valid for:
Advanced Power TOPLED / Golden DRAGON / Micro SIDELED 3010 / Mini TOPLED / PointLED / Multi TOPLED / MULTILED / OSLON Black Flat / OSLON SX / OSLON Black / OSLON Compact / OSLON Signal / OSLON LX / OSLON MX / SIDELED / OSRAM OSTAR Headlamp Pro / SYNIOS / Power SIDELED / Power TOPLED / TOPLED

Abstract

Combined with other components into one product, LEDs are used in a wide variety of application areas. LEDs are exposed to various environments under conditions that deviate from the qualification conditions. In order to evaluate possible impacts, LEDs are examined under standard operating conditions.

However, as not all possible application conditions can be simulated, this application note only illustrates certain extreme conditions, which could influence the lifetime of LED components. It provides explanations as how these effects can occur and how they might be avoided. This application note focuses on environmental conditions that affect the metal structures and might lead to corrosion. Therefore, the OSRAM Opto Semiconductors robustness classes will be introduced. In general, all application systems should be tested as to whether the materials and components used harmonize with each other.

Author: Retsch Stefanie / Brandl Michael

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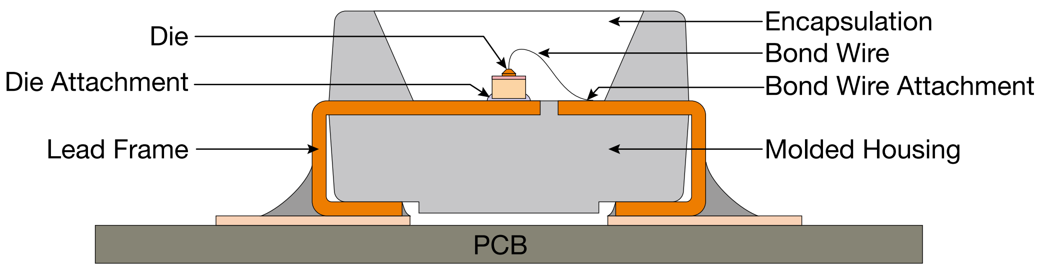
A. LED designs

Depending on the environmental conditions all parts of an LED can be affected by corrosion or deterioration. In order to understand the influencing factors it is beneficial to be familiar with the exemplary structure of an SMT (surface mounted technology) LED as shown in Figure 1. An SMT LED consists of a metal lead frame, and a die latter glued or soldered to the lead frame to create one of the two contacts of the LED. For the second contact pin of the LED the die is connected electrically by a bond wire. Finally, the LED is cast with an encapsulation to cover the die and wire. For encapsulation mainly silicone or epoxy are used.

Figure 1: Basic structure of an SMT LED



LEDs can be realized in different ways by using various materials. The selection of the material always depends on the final characteristics the LED should show. All materials have their advantages for use in various applications, however the material influences the robustness of the LEDs towards corrosive gases.

Encapsulation materials

For LED encapsulation mainly two different materials are used:

- Epoxy
- Silicone

Epoxy encapsulations provide good mechanical stability and high resistance to gases. In addition, the adhesion to the surface is good. However, the radiation of high power LEDs, especially blue and white LEDs, may lead to fast aging and may discolor the epoxy. Furthermore, the temperature stability is not as high as for silicone, especially for high power LEDs.

In contrast, for silicone encapsulations the maximum operating temperature can be increased to more than +125 °C. Silicone possesses a high optical transparency and a higher aging stability to radiation, in particular to blue and white light. It also provides good chemical resistance, but it is more permeable for gases and small molecules. Thus, harmful substances can diffuse through the encapsulation and affect the subsurface.

Ultimately which encapsulation can be used always depends on the LEDs characteristics.

Electrical connection

The electrical connection between the die and the leads can be realized through a silver containing glue or by soldering. Both methods are used at OSRAM Opto Semiconductors.

The silver glue provides a mechanical connection with good electrical and thermal conductivity. Moreover, silver has a good light reflection.

Soldered chips provide good stability relating to corrosion. However, not all products can be equipped with a soldered chip interface.

Plating of the lead frame

The lead frame can be plated with different metals. Inside the LED silver or gold is often used.

Silver plating provides the lead frame with high light reflectivity and good connectivity. In general, the plating has good stability against a lot of environmental impacts. However, there are various harmful substances which can affect the LED, e.g. sulfurous compounds.

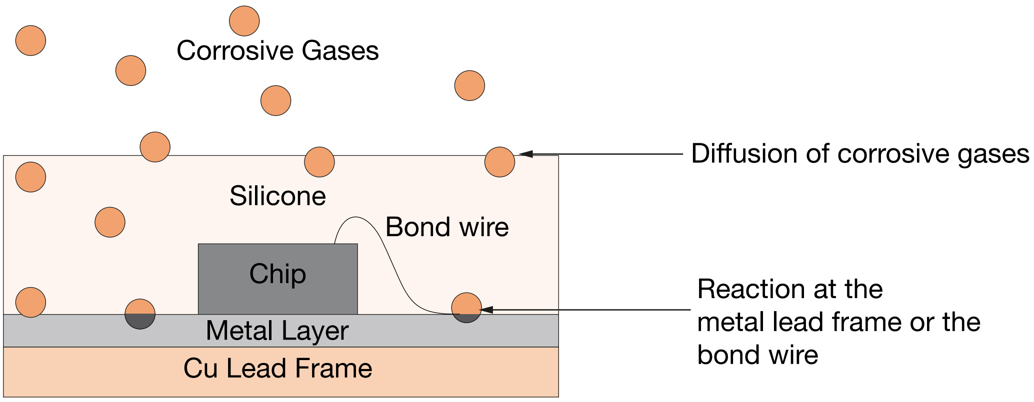
In contrast, gold plating offers higher chemical stability, especially against sulfur. However, the light reflection is not as high as with silver plating, a characteristic which has to be considered in some LED products.

The lead frame outside of the LED housing can be plated with different materials. Among others, pure tin, gold or gold alloys and also pure silver are used.

B. How corrosion occurs

Corrosive gases can penetrate through the encapsulation of the LED, especially when a silicone encapsulation is used (Figure 2). This can lead to corrosion of the different metals used in the LED. If gases diffuse through the encapsulation, the lead frame may become discolored. This corrosion can affect the performance and the lifetime of the LED negatively and lead to a failure.

Figure 2: Diffusion of corrosive gases



Example of sulfur contamination

There are various harmful substances capable of causing corrosion or damage to the electronics in general or the LED specifically. To describe this effect, H_2S was selected as an example, because high concentrations of sulfur compounds can be a reason for defective LEDs. Various test results confirm that OSRAM Opto Semiconductors LEDs do not intrinsically contain harmful substances. It is known that H_2S can evaporate especially from rubber-like materials. Because of this a special focus should be laid on a low to zero content of sulfur compounds or low evaporation properties of these materials, when used near LEDs.

As an example a silicone cast LED and the effect of hydrogen sulfide is shown in Figure 3. Without coming into contact with the harmful gas, the lead frame of the LED has a shiny surface. But after contact with a system containing H_2S the surface turns brown or black, noticeable by visual inspection (for LEDs with a clear casting). The presence of a micro climate, containing sulfur compounds, causes a chemical reaction of the diffused gases with the silver lead frame plating. The silver layer transforms into silver sulfide. In this particular case the corrosion leads to an open contact, as the bond wire is disconnected. This happens because silver sulfide is not electro-conductive and its volume is greater than the volume of silver. This then leads to a mechanical separation between the bond wire and the connecting lead. In other cases it can lead to an open contact because of lifted glue or other functional failures.

Figure 3: Example of a silicone cast LED with a silver lead frame in contact with a hydrogen sulfide environment.

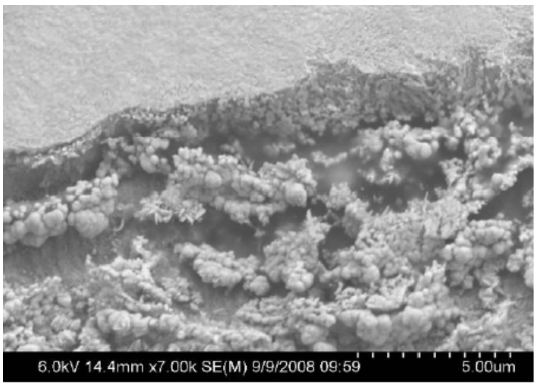
Before the contamination with hydrogen sulfide

After the contamination with hydrogen sulfide

The corrosion caused a disconnected bond wire. The LED will show an open contact.

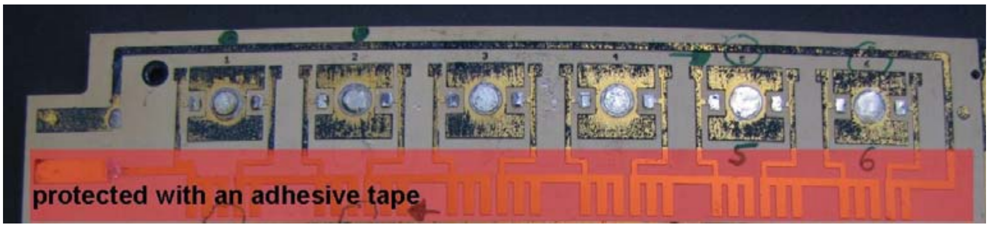
The verification via SEM (scanning electron microscope) and EDX (energy-dispersive X-ray) analysis illustrates the effect of the corrosion. As can be seen in Figure 4 the sulfur-containing compound reacts with the lead frame surface to form silver sulfide. In extreme cases the corrosion can damage the connection between the wire or the chip and the lead frame. This can result in a lifted wire or lifted glue, each of which results in an open contact.

Figure 4: SEM picture of the corroded Ag-surface (silver sulfide)



Not only the silver lead frame of the LEDs can be affected, but also copper materials. For example, coated layers on printed circuit boards (PCBs) can corrode. Figure 5 shows a detailed view of an IMS-PCB which was exposed to an atmosphere containing corrosive sulfur-components. During the sulfur corrosion test the red highlighted area of the surface was covered with an adhesive tape. As can be seen the unprotected contacts, especially the copper layers, are affected by the sulfur despite their gold finish.

Figure 5: Example of an IMS-PCB exposed to a corrosive sulfur atmosphere



Corrosion can occur due to other harmful substances at any part of the LED as well. Other metals than those previously mentioned and even plastic materials such as the LED housing, can be affected if the substances in the environment does not harmonize with the material. So the application system always needs to be tested in relation to the harmful substances from and around the application in conjunction with the LED materials. In particular, special care must be taken in sealed environments.

C. How corrosion can be avoided

To avoid any corrosion, the best way is to avoid harmful substances in proximity to the LEDs. Even small quantities of harmful substances can lead to corrosion. Even if the LED is only in contact with corrosive gases during the processing steps, such as in machines of the production line, this could have negative effects. In these cases damage to the LED component can usually already be observed prior to the real system setup. Especially sulfur contamination should be avoided. The following list shows some examples which may be the source of corrosive substances, in particular H_2S:

Actual cases known:

- O-rings
- Gaskets
- Organic rubber
- Foam pads
- Rubber sealing
- Elastomer vulcanized with sulfur
- Anti-vibration pads

Other theoretical sources:

- Thermal conductive pad
- Contaminated PCB material
- Solder resist
- Stop-off lacquer

- Paper and paperboards
- Industrial environment with high sulfur or sulfide concentration

If harmful substances cannot be fully avoided, an LED with higher robustness towards corrosion should be used. However, it must be considered that the robustness towards corrosion is limited, depending on the concentration of the harmful materials. In general, heat, humidity and light among others are able to accelerate a corrosive process. However, the main influencing factors can be limited to concentration level and temperature.

D. How to find the right LED for the application

OSRAM Opto Semiconductors offers a large product portfolio with various LED types to the customer. Each of the LEDs has different properties and can therefore be used in different applications. The customer can choose from a variety of LEDs, which are classified according to their properties. For example, the LEDs have a different robustness towards corrosive gases. To categorize the robustness of each LED type OSRAM Opto Semiconductors uses different tests. These test results are expressed in robustness classes.

For a categorization regarding robustness OSRAM Opto Semiconductors offers different classes, based on different test conditions:

- Class 0: not tested
- Class 1: 25 °C / 75 % RH / 200ppb SO_2, 200ppb NO_2, 10ppb H_2S, 10ppb Cl_2 / 21 days (EN 60068-2-60 (Method 4))
- Class 2: 25 °C / 75 % RH / 10ppm H_2S / 21 days (IEC 60068-2-43)
- Class 3: 40 °C / 90 % RH / 15ppm H_2S / 14 days

After each test a visible and electrical inspection follows and the LEDs are classified as grade A or grade B.

Grade A. The LEDs passed the test without any significant change in electrical or optical characteristics. Subcomponents of this LED contain, in addition to other substances, metal filled materials. Metal filled materials can be affected by environments that contain traces of aggressive substances. Therefore, it is recommend to minimize LED exposure to aggressive substances during storage, production and use.

Grade B. The LEDs passed the test without any significant change in electrical characteristics, but with visible alterations in terms of discoloration. Subcomponents of this LED contain, in addition to other substances, metal filled materials including silver. Metal filled materials can be affected by environments that contain traces of aggressive substances. Therefore, it is recommended to minimize LED exposure to aggressive substances during storage, production and use. LEDs that showed visible discoloration when tested, using the tests described showed no performance deviations within failure limits during the stated test duration. Respective failure limits are described in the IEC60810.

An overview of the robustness classes can be found in Table 1. The category for each LED can be seen in the respective LED data sheet.

Table 1: Overview of the OSRAM Opto Semiconductors robustness classes

Class	Grade A	Grade B	Test Conditions
0	n.a.	Discoloration possible[1]	not tested
1	No visible discoloration[1]	Discoloration possible[1]	25 °C / 75 % RH / 200ppb SO_2, 200ppb NO_2, 10ppb H_2S, 10ppb Cl_2 / 21 days (EN 60068-2-60 (Method 4))
2	No visible discoloration[1]	Discoloration possible[1]	25 °C / 75 % RH / 10ppm H_2S / 21 days (IEC 60068-2-43)
3	No visible discoloration[1]	Discoloration possible[1]	40 °C / 90 % RH / 15ppm H_2S / 14 days (stricter than IEC 60068-2-43)

[1]: Microscope: 50x magnification

The results of these classification tests show that LEDs with a silver lead frame and a silicone encapsulation provide a different robustness class than LEDs with a different material design. As mentioned before, OSRAM Opto Semiconductors offers its customer a large portfolio of products, suitable for a variety of applications, each with different requirements. Thus, there are many reasons why LEDs are produced with different material compositions. As explained previously, any LED material can be affected by harmful substances.

It is possible that an application contains substances that have not been tested within these robustness classes. OSRAM Opto Semiconductors performs extensive qualification tests to ensure stability and to improve the products. However, it is not possible to test all LEDs for all potential application environments. The robustness classes give a first indication, but it is recommended to test whether the LEDs harmonize with the materials used in the system for the final application.

OSRAM Opto Semiconductors provides a large product range for use in a large number of different applications. Care is taken that standards and customer requirements can be fulfilled. Therefore, a large product choice is offered. For further information and support please contact OSRAM Opto Semiconductors.

Don't forget: LED Light for you is your place to be whenever you are looking for information or worldwide partners for your LED Lighting project.

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ABOUT OSRAM OPTO SEMICONDUCTORS

OSRAM, Munich, Germany is one of the two leading light manufacturers in the world. Its subsidiary, OSRAM Opto Semiconductors GmbH in Regensburg (Germany), offers its customers solutions based on semiconductor technology for lighting, sensor and visualization applications. OSRAM Opto Semiconductors has production sites in Regensburg (Germany), Penang (Malaysia) and Wuxi (China). Its headquarters for North America is in Sunnyvale (USA), and for Asia in Hong Kong. OSRAM Opto Semiconductors also has sales offices throughout the world. For more information go to www.osram-os.com.

OSRAM Opto Semiconductors GmbH

Head office:

Leibnizstr. 4
93055 Regensburg
Germany
www.osram-os.com